(NASA-CR-146658) EXPERIMENT DEFINITION USING THE SPACE LABORATORY, LONG DURATION EXPOSURE FACILITY, AND SPACE TRANSPORTATION SYSTEM SHUTTLE Final Report (Georgia Inst. of Tech.) 74 p HC $4.50 CSCL 22A G3/13

N76-20171

Unclas 21433

FINAL REPORT

EXPERIMENT DEFINITION USING THE SPACE LABORATORY, LONG DURATION EXPOSURE FACILITY, AND SPACE TRANSPORTATION SYSTEM SHUTTLE

by

Albert P. Sheppard
Joan M. Wood

NASA Grant No. NSG 1200

14 March 1976

Georgia Institute of Technology

FINAL REPORT

EXPERIMENT DEFINITION USING THE SPACE LABORATORY, LONG DURATION EXPOSURE FACILITY, AND SPACE TRANSPORTATION SYSTEM SHUTTLE

by

Albert P. Sheppard
Joan M. Wood

NASA Grant No. NSG 1200

14 March 1976

Georgia Institute of Technology

TABLE OF CONTENTS

Introduction

The Space Shuttle Transportation System, the Spacelab, and the Long Duration Exposure Facility will have begun operation by the end of this decade. These facilities will provide researchers with an unprecedented opportunity to carry on a large number of experiments in the unique environment of space. The National Aeronautics and Space Administration (NASA) has embarked on an ambitious program for informing the scientific community of the opportunities available and for soliciting inputs on how best to exploit these new opportunities.

One of the NASA programs has been the funding of major technological universities to assist in the optimization of these space programs for maximizing their scientific and engineering pay-off. The Georgia Institute of Technology proposed participation in this NASA program and was funded for the period from 15 June 1975 to 14 March 1976. The Institute is especially well-qualified for the program in that it confers more than 1000 degrees annually in the engineering disciplines alone, as well as having strong programs in the natural and applied sciences, industrial management and architecture. Its research program is funded at over $16 million annually, and, at any one time, over 600 sponsored research projects in engineering and science are underway. In addition to its own research, the Institute maintains a close relationship with industry and with other academic institutions.

The objective of the program at Georgia Tech was "to define experiments which will utilize the space laboratory, the long duration exposure facility, and space transportation system shuttle being developed by NASA." Both

passive and active candidate experiments were to be considered. In the definition of candidate experiments, a prescribed format was to be followed so that consistent and comprehensive evaluation data would be available to NASA. The format includes: Experiment Title; Experimenter; Technical Abstract; Benefits/Justification; Technical Discussion of Experiment Approach and Objectives; Related Work and Experience; Experiment Facts (Space properties used, environmental constraints, shielding requirements, if any, physical description, sketch of major elements, etc.); Experiment Hardware; Research Required to Develop Experiment; Special Requirements; Cost Estimate; Safety Considerations; and Interactions with Spacecraft and other Experiments.

In addition, a commitment was made that the responsible program personnel at Georgia Tech would maintain close liaison with appropriate project personnel from NASA to minimize duplication of effort and to make certain the program output was compatible with NASA objectives.

Methodology

In order to obtain candidate experiments for the Shuttle, Spacelab, and Long Duration Exposure Facility, the project team first decided to hold meetings with the departments within the Institute which were thought to be the most promising sources of input. Meetings were held with the faculty of the Schools of Engineering Sciences and Mechanics, Mechanical Engineering, Aerospace Engineering, and Electrical Engineering to explain the program, to offer assistance in defining experiments and to answer questions. These meetings did not produce the desired response. They were sparsely attended and did not generate any candidate experiments.

The project team decided that a change in approach was necessary. The Deans of the Colleges and the Director of the Engineering Experiment Station were requested to send letters to their department heads explaining the program and asking for their support and cooperation. After the letters were sent out, the department heads were interviewed individually by members of the project team. During these interviews, it was found that the primary reason researchers were unwilling to submit candidate experiments was that they did not believe that they had any chance of getting their proposals funded as a possible outcome of participating in this program. The consensus seemed to be that all of NASA's funding went to a select group of researchers and that if one was not already a member of this group, it would be an idle exercise to submit proposals without developing personal contacts at NASA. Inevitably, the questions of how much had been allocated to this program by NASA and of how many universities were eligible for the funds were the principal topics raised after the technical scope of the mission had been described.

Several units outside of the Institute were also contacted. They included Lockheed Aircraft, Electromagnetic Sciences, Radiation, Inc., Division of Harris Intertype, Scientific Atlanta, The Atlanta University Center, and Georgia State University. No candidate experiments were received from these sources even though rather complete information including the proposal forms were furnished each organization.

A final meeting was held at Georgia Tech at which Dr. John Dibattista, Mr. William Kinard, and Mr. Carol Kiser from NASA presented an overview

of the program and answered questions. Members from all departments were invited to attend this meeting; however, once again the meeting was not well attended relative to the publicity given in advance of the briefing. Nevertheless, some new interest in the program was generated and some candidate experiments were submitted as a result of this meeting.

Overall, it was felt that the individual approach was the most successful. This was because the individuals were more willing to express their reservations about the program in private than they were in open meetings, and once their concerns were out in the open, they could be dealt with on a personal basis.

Self-Evaluation

The proposals that were accepted for inclusion in this report were screened to make certain that they fitted the objectives of this project. The proposals were required to be new proposals which did not duplicate existing NASA projects and if destined for the Long Duration Exposure Facility, they were required to meet the size, weight, and safety requirements of that facility.

Results

Eight candidate experiments are included in this report. They come from academic departments within the Institute as well as from the Engineering Experiment Station. They are all of excellent quality and demonstrate a high level of technical competence. They are as follows:

1. "Transient Heat Pipe Study" submitted by G. T. Colwell of the Mechanical Engineering Department. The purpose of this experiment is to study the transient effects on low temperature heat pipes operating in zero gravity. Heat pipe fluid regimes include start-up from super critical conditions and low pressures. Estimated cost is $100,000.
2. "Conversion of Microwave Energy into Rotational Motion for Earth Orbital Application," submitted by R. C. Michelson of the Applied Engineering Laboratory, Engineering Experiment Station. The purpose of this experiment is to test the direct conversion of microwave energy into omnidirectional rotational energy as a method of yaw and pitch system control. Estimated cost is $50,000.
3. "Radio Astronomy of Molecular Oxygen from the Space Shuttle," submitted by Mr. J. J. Gallagher of the Engineering Experiment Station, Dr. G. T. Wixon, University of Cork, Ireland, Dr. L. Snyder, University of Virginia, and Dr. W. Welch, University of California. The purpose of this experiment is to determine the location of and concentration of molecular oxygen. Estimated cost is $1,069,000.
4. "Effect of Space Environment on the Mechanical and Electromagnetic Properties of Exposed Microstrip Antennas," submitted

by J. W. Cofer of the Engineering Experiment Station. The purpose of this experiment is to deploy and retrieve several typical antenna elements and determine any degradation in electromagnetic performance due to exposure in the space environment. Estimated cost is $30,750.

5. "Photocatalytic Syntheses on Silicious Particles under Conditions of Weightlessness and Solar Ultraviolet Light," submitted by Dr. J. S. Hubbard of the Biology Department and Dr. Gerald E. Voecks of the California Institute of Technology. The purpose of this experiment is to assess the contributions of photocatalytic synthesis in chemical evolution in planetary atmospheres and interstellar space. Estimated cost is $21,900.

6. "Experimental Space Craft Heat Engine," submitted by R. R. Sheppard of the Engineering Experiment Station. The purpose of this experiment is to evaluate the feasibility of utilizing the extreme temperature differences aboard orbiting spacecraft to produce direct mechanical power. Estimated cost is $123,424.

7. "Space Testing of Holographic Data Storage Crystals," submitted by T. K. Gaylord and W. R. Callen of the School of Electrical Engineering. The purpose of this experiment is to determine the space-worthiness and to identify any

possible physical effects of space on holographic data storage crystals. Estimated cost is $25,300.

8. "Creep-Rupture Characteristics of Refractory Metals," submitted by Dr. J. Richard Williams, Associate Dean for Research, College of Engineering. The purpose of this experiment is to determine the creep-rupture characteristics of refractory metals which might be used in constructing solar-thermal and nuclear power plans in space. Estimated cost $93,000.

CANDIDATE EXPERIMENTS

EXPERIMENT TITLE Transient Heat Pipe Studies

EXPERIMENTER(S) Dr. Gene T. Colwell

POSITION Associate Professor of Mechanical Engineering

ORGANIZATION Georgia Institute of Technology

ADDRESS School of Mechanical Engineering

Atlanta, Georgia 30332

TELEPHONE (404) 894-3246

TECHNICAL ABSTRACT (50 words or less)

The purpose of this experiment is to obtain transient operating data on low temperature heat pipes operating in zero-G. The regimes under study would include start-up from supercritical conditions (for the heat pipe working fluid) and low pressures.

BENEFITS/JUSTIFICATION FOR RESEARCH PROJECT

Heat pipes seem to have great promise for many uses in space. Unfortunately little detailed information is available on transient behavior in zero-G. Of particular interest is how the device starts from the supercritical state. We propose to study a well instrumented test pipe under a wide variety of transient conditions.

1.0 TECHNICAL DISCUSSION OF EXPERIMENT APPROACH AND OBJECTIVES

The purpose of the experiment is to gather extensive data related to low temperature transient heat pipe operation in zero-G. The data would be correlated to yield design expressions for use in planning future equipment which uses heat pipes.

I currently have under way a theoretical study (using both digital and analog computers) aimed at predicting transient zero-G performance of low temperature pipes. Data obtained under the proposed program would be of great value in checking our theoretical models. The verified models would then be available to the heat pipe designer.

2.0 DISCUSS YOUR RELATED WORK AND EXPERIENCE

I have been working with heat pipes for about nine years. The work performed has included theoretical, experimental, and design projects. NASA, the U. S. Army, the U. S. Navy, and the Trane Company have supported our work. Several graduate students (M.S. and Ph.D.) have chosen the heat pipe as a thesis research project. Numerous publications and reports have resulted from the work.

I have been working for sixteen years in thermal science research, design, and teaching. The attached resume outlines my experience.

3.0 EXPERIMENT FACTS

3.1 WHAT SPECIFIC SPACE PROPERTIES WILL IT MAKE USE OF?

Zero G and low temperature

3.2 WHAT IS THE PREFERRED LOCATION ON LDEF?

LEADING SIDE	______	SPACE END	X
TRAILING SIDE	______	INTERIOR	______
EARTH END	______		

3.3 WHAT ARE THE ENVIRONMENTAL CONSTRAINTS? (List extremes)

3.3.1 TEMPERATURE RANGE

Wide temperature range desireable

3.3.2 VIBRATION AND SHOCK (pre- and post-launch and orbit)

None

3.3.3 ATTITUDE CONTROL

None

3.3.4 RADIATION (particles and electromagnetic)

None

3.3.5 VACUUM (space)

None

3.3.6 ATMOSPHERE (pre-, during, and post-launch and return)

Experiment may need to be cooled prior to launch

3.3.7 MAGNETIC FIELD

None

3.4 WHAT SPECIAL PROTECTION MUST BE PROVIDED TO PROTECT THE EXPERIMENT FROM THE EARTH AND SPACE ENVIRONMENTS?

None

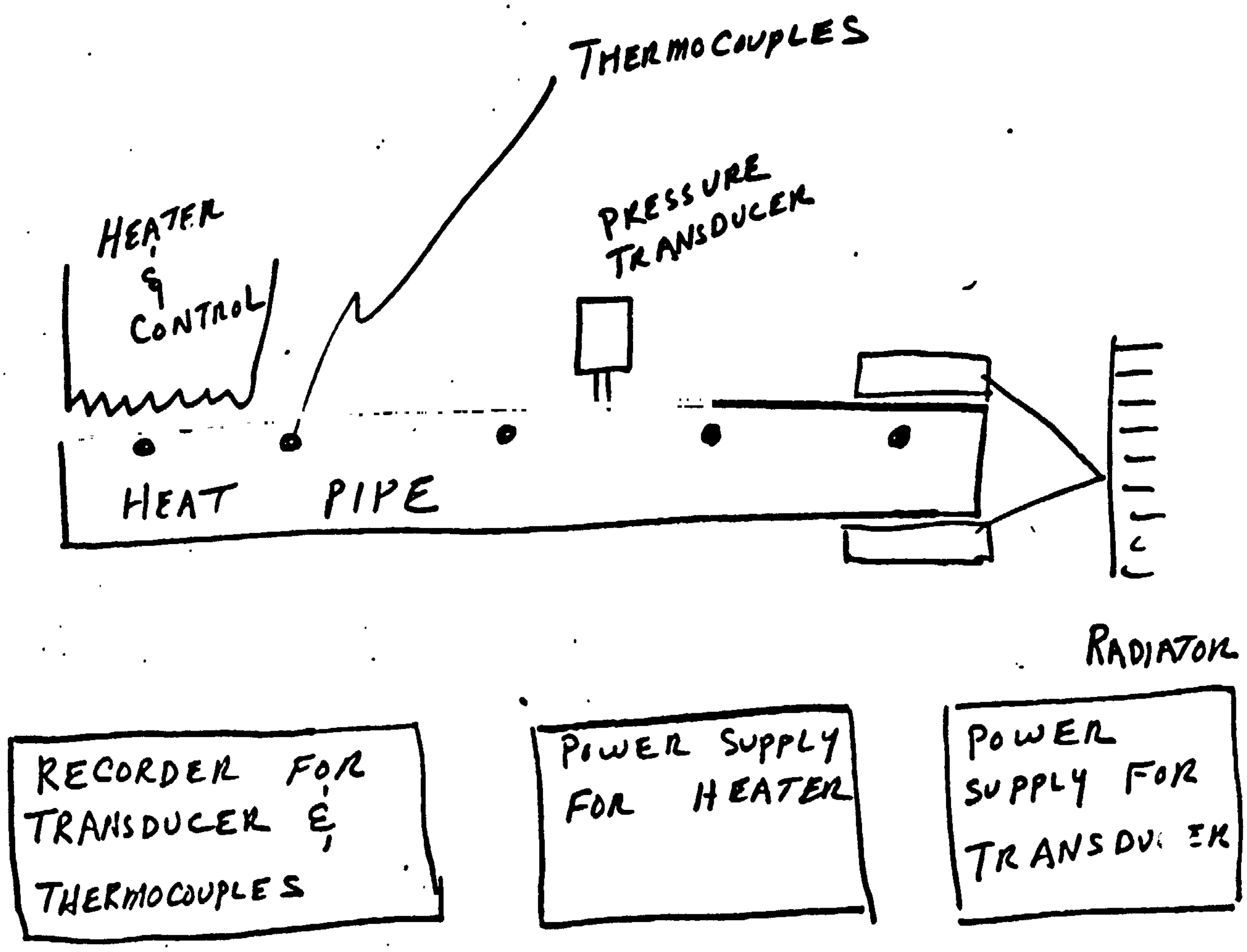
3.5 PHYSICAL DESCRIPTION

3.5.1 MASS 150 lb_m

3.5.2 VOLUME 30 ft^3

3.5.3 SURFACE AREA REQUIRED

3.6 SKETCH EXPERIMENT INCLUDING MAJOR COMPONENTS AND LAYOUT FOR EXPOSURE EXPERIMENTS.



4.0 EXPERIMENT HARDWARE (With reference tc the sketch in 3.6, briefly describe the hardware, indicating what is currently available and what must be developed.)

1. Power Supplies are on hand

2. Heater would be custom made

3. Radiator would be custom designed to fit vehicle

4. Heat pipe would be custom built and ground tested at Georgia Tech

5. Instrumentation is standard.

5.0 DISCUSS RESEARCH REQUIRED TO DEVELOP EXPERIMENT

Due to long on-going heat pipe research (9 years) at Georgia Tech, technology is now available to design and build experimental package.

6.0 DISCUSS SPECIAL FACILITIES REQUIRED FOR DEVELOPMENT AND ANALYSIS

None

7.0 COST ESTIMATE (Manpower)

		mm	$
7.1	MANPOWER (Man-months and dollars)		
7.1.1	EXPERIMENT DESIGN	6	20,000
7.1.2	DEVELOPMENT OF IMPLEMENTATION PLAN	2	6,700
7.1.3	GROUND-BASED TESTING	3	10,000
7.1.4	PRE-LAUNCH (analysis)	1	3,300
7.1.5	DURING MISSION	2	6,700
7.1.6	POST-LAUNCH (analysis)	6	20,000
7.2	HARDWARE (Dollars)		
7.2.1	ENGINEERING PROTOTYPE		-0-
7.2.2	HARDWARE FABRICATION		20,000
7.2.3	PRE- AND POST-LAUNCH		5,000
7.3	OTHER DIRECT COSTS (computer, travel, etc.)		5,000
		Total	$96,700

8.0 SAFETY CONSIDERATIONS (Discuss potential hazards to ground and flight personnel, spacecraft, and other experiments.)

None

9.0 DISCUSS INTERACTIONS WITH SPACECRAFT AND OTHER EXPERIMENTS (e.g., thermal, radiation, mechanical).

This experiment needs to radiate thermal energy to space.

BIOGRAPHICAL INFORMATION

Gene Thomas Colwell
August, 1975

Personal Data

Birth Date:	[redacted]
Wife:	Peggy Ann (Fletcher) Colwell
Foreign Languages:	French (read), German (read), Spanish (read and speak moderately well)
Citizenship:	United States

Education

B.S.M.E.	University of Tennessee	June 1959
M.S.M.E.	University of Tennessee	June 1962
PhD.E.S.	University of Tennessee	March 1966

Emory University Medical School - Physiology

Georgia Institute of Technology - Foreign Language Study

Professional Information

I. Full time "Research Engineer" at Oak Ridge National Laboratory: (June 1959 to September 1962)

1. Planning, design, and testing of turbine and pump components for small nuclear powered generators for space vehicles.
2. Research into hydrodynamic and hydrostatic gas bearing performance.
3. Design (aerodynamic, thermodynamic, heat transfer, lubrication, and stress analysis) of large high temperature special purpose compressors and pumps for various reactors.
4. Overall system planning and analysis.

II. Full time "Instructor" at the University of Tennessee: (September 1962 to December 1965)

1. Dynamic shaft seal research.

2. Low density flow studies - free molecular, slip and continuous flow in tubes and nozzels.

3. Teaching (Junior and Senior Courses)

   a. Thermodynamics
   b. Heat Transfer
   c. Kinematics
   d. Laboratory Lecture

III. Full time "Design Specialist" at Oak Ridge National Laboratory: (December 1965 to September 1966)

1. Planning and preliminary design of proposed nuclear desalting plants.

2. Design and planning of auxilliary space power plants.

3. Heat transfer analysis.

IV. "Assistant Professor" (September 1966 to June 1971) and "Associate Professor" (June 1971 to present) of Mechanical Engineering, Georgia Institute of Technology:

1. Teaching graduate courses in heat transfer, gas turbines, fluid mechanics and thermodynamics.

2. Teaching undergraduate courses in heat transfer, fluid mechanics, turbomachinery, and thermodynamics.

3. Research work concerning a unique type of gas turbine engine.

4. Research work concerning "Heat Pipes".

5. Research work on high lift wing structures.

6. Air Pollution lectures.

V. "Post Graduate Professor", University of Carabobo, Valencia, Venezuela. January through March 1972: Graduate Courses in Thermodynamics and Fluid Mechanics.

VI. Consulting Work:

1. Oak Ridge National Laboratory - Oak Ridge, Tennessee.

2. Scientific Atlanta - Atlanta, Georgia.

3. Air Preheater Company - Wellsville, New York.

4. Arnall, Golden & Gregory - Attorneys, Atlanta, Georgia.

5. Lockheed Georgia - Nuclear Division, Dawsonville, Georgia.

6. Automated Disposal Company - Atlanta, Georgia.

7. Troutman, Sanders, Lockerman & Ashmore - Attorneys, Atlanta.
8. The Bay Tree Company - Atlanta, Georgia.
9. Energy Sciences Incorporated - McLean, Virginia.
10. Complan, Inc. - Atlanta, Georgia.
11. Solomon and Associates - Atlanta, Georgia.
12. Air Conditioning Atlanta - Atlanta, Georgia.
13. Flav-O-Rich, Inc. - Columbus, Georgia.
14. Seaboard Cost Line Railroad Company (Counsel - Wingo, Bibb, Foster Cornwell & Strickland) Birmingham, Alabama.
15. Radiation Inc. - Melbourne, Florida.
16. Swift, Currie, McGhee & Hiers - Attorneys, Atlanta.
17. Industrial Development Division, Engineering Experiment Station, Georgia Tech.
18. Dekalb County Health Department - Air Pollution Control.

VII. Honors and Memberships:

1. American Men of Science.
2. Who's Who in the South and Southwest.
3. American Society of Mechanical Engineers.
4. Pi Tau Sigma.
5. Sigma Xi.
6. Registered Engineer - State of Georgia (#5993).
7. U. S. Security Clearance - AEC Issued.
8. Dictionary of International Biography - London, England.
9. Who's Who in Georgia.

<u>Publications</u>

1. "An Aerodynamic - Thermodynamic Study of Centrifugal Compressors", Oak Ridge National Laboratory, ORNL-3294, December 4, 1962.

2. "Calculation of Critical Frequencies with a Digital Computer", Oak Ridge National Laboratory ORNL CF-61-12-41, December 20, 1961.

3. "Analytical and Experimental Study of Very Low Density Subsonic Flow of Gases in Converging Sections", University of Tennessee PhD Thesis, December 1965.

4. "Design of a Potassium Turbine Simulator", Oak Ridge National Laboratory ORNL-66-6-70, June 30, 1966.

5. "Low Density Nozzle Flow", Transactions of ASME, Journal of Basic Engineering, Vol. 91, Page 81, March 1969.

6. "A Study of Noncondensable Effects in a Heat Pipe", Journal of the American Nuclear Society, Nuclear Technology, Vol. 10, March 1971.

7. "Parametric Study of Two-Dimensional Turbulent Wall Jet in a Moving Stream with Arbitrary Pressure Gradient", AIAA Journal, Vol. 9, No. 11, November 1971, pp. 2156-2165.

8. "Parametric Relations for Ordinary and Confluent Turbulent Boundary Layer Flows", AIAA Journal, Vol. 11, No. 5, May 1973, pp. 583-584.

9. "Turbine-Compressor", United States Patent Number 3,751,908, August 14, 1973.

10. "Gas Distribution Measurements from ^{41}Ar Activity", Isotopes and Radiation Technology, Vol. 9, No. 4, Summer 1972.

11. "History and Air Pollution", The Georgia Professional Engineer, Vol. XXV, No. 6, September 1972.

12. "Some Important parametric Relations for Ordinary and Confluent Turbulent Boundary Layer Flows", NASA N-73-13297, Available U.S. Commerce Dept., National Technical Information Service, February, 1973.

13. "Heat Pipe Cooled Microwave Window", Final Report to U.S. Army Safeguard Command, Huntsville, Alabama, Contract DAHC60-72-C-0144 January 1973, Georgia Tech Projects A-1434 and E25-627.

14. "A Heat Pipe Model Accounting for Variable Evaporator and Condenser Lengths", AIAA Journal, Vol. 12, No. 9, pp. 1261-1267, Sept. 1974.

15. "Analysis of High Lift Wing Systems", Aeronautical Quarterly, Royal Aeronautical Society, Vol. XXVI, May 1975, pp. 88-103, London.

16. "Heat Pipe Cooled Microwave Window", U.S. Army Ballistic Missile Defense Agency, Huntsville, Alabama, Contract No. DAHC60-73-C-0088, February 1974, Georgia Tech Projects E-25-635 and A-1532.

17. "Thermal Considerations for Microwave Structures", International Microwave Power Institute, 1974, Microwave Power Symposium, Marquette University, May 29, 1974, Milwaukee, Wisconsin.

18. "High Power Microwave Window Design", 1974 IEEE International Microwave Symposium, Georgia Institute of Technology, Atlanta, Georgia, June 12, 1974.

19. "Heat Pipe Cooled Microwave Phase Shifters and Other Devices", Army Science Conference, June 18-21, 1974, West Point, N.Y.

20. "Thermal Control and Heat Pipe Investigation Report", submitted by Radiation Inc. of Melbourne, Florida to The Office of Naval Research, Contract No. N00014-73-C-0446, February 6, 1974.

21. "Performance of a Heat Pipe in a Microwave Field", Und~~er Review by~~ Journal of Microwave Power. ACCEPTED FOR PUBLICATION

22. "High Power Microwave Window With a Microwave Transparent Cooling Mechanism", Toisieme Colloque International sur Les Fenetres Electromagnetiques, Ecole National Superieure de Techniques Avancees, Paris, 10-12 September 1975.

23. "Cryogenic Heat Pipe Performance, Report I", NASA Grant NSG-2054, July 1, 1975.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

EXPERIMENT TITLE CONVERSION OF MICROWAVE ENERGY INTO ROTATIONAL MOTION FOR EARTH ORBITAL APPLICATIONS

EXPERIMENTER(S) Robert C. Michelson

POSITION Assistant Research Engineer

ORGANIZATION Radar Technology Division, Applied Engineering Laboratory

ADDRESS Engineering Experiment Station, Georgia Institute of Technology
Atlanta, Georgia 30332

TELEPHONE (404) 894-3525

TECHNICAL ABSTRACT (50 words or less)

This experiment would test the direct conversion of microwave energy into omnidirectional rotational energy. Angular motion would result from a magnetic moment acting against the earth's magnetic field. The power to generate the magnetic moment would be derived from remotely transmitted microwave energy.

BENEFITS/JUSTIFICATION FOR RESEARCH PROJECT

The benefits of this system over rocket yaw and pitch for earth satellites are: (1) the system is completely passive; (2) no refueling of yaw and pitch attitude rockets is ever necessary; (3) the system is damped and therefore needs no retro forces applied to bring it back into equilibrium; (4) the system is light weight; (5) more precise than rocket attitude control; and (6) contains no moving parts. Possible applications might be for (1) attitude control for spaceborne solar furnace mirrors; (2) midcourse attitude changes for satellites controlled from remote stations; (3) precise attitude control for unmanned orbital observatories; and (4) precise attitude control for radar surveillance satellites.

1.0 TECHNICAL DISCUSSION OF EXPERIMENT APPROACH AND OBJECTIVES

This experiment would test the direct conversion of microwave energy into omnidirectional rotational energy. Information concerning the desired orientation of a passive test-bed drone would be transmitted. Three drone antennas situated in an orthogonal array would receive the transmission whereupon the transmitted energy would be continuously rectified and stored. A portion of the stored energy would be used to energize low-power logic circuitry. This circuitry would measure the signal strength received by each of the three orthogonal antennas. A calculation would then yield a vector indicating the relative location of the transmitting source. Simultaneously a modulation indicating the desired orientation of the drone relative to the transmitting source would be demodulated from the microwave carrier by other low-power circuits. The bulk of the presently stored electrical energy would then be diverted into a set of three orthogonal coils. The logic circuitry would determine the amount of current to be sent through each coil such that a magnetic vector would be produced in the proper direction to interact with the earth's magnetic field. This magnetic vector would create a force on the drone until the drone magnetic vector was colinear with the magnetic vector of the earth. At this point the drone should be in the proper orientation with respect to the transmitting source and the transmissions could cease.

A battery operated digitally controlled modulator and microwave transmitter would be located in the LDEF. A passive drone test bed would either be manually placed in a synchronous orbit with the LDEF or automatically ejected from the LDEF into such an orbit. Tests would be performed during the mission to measure the angular accuracy of positioning and the angular drift between positionings. Response times of the system would also be monitored.

2.0 DISCUSS YOUR RELATED WORK AND EXPERIENCE

The Georgia Tech Engineering Experiment Station (EES) has extensive experience in microwave techniques and system fabrication. Five major microwave laboratories are maintained within the Station (microwave power lab, microwave antenna lab, electromagnetic compatibility lab, communications systems lab, electromagnetics measurements lab compact indoor measurement range) as well as a solid state circuits lab, electro-optical/infrared lab, and machine/model shop. Below is a sampling of Georgia Tech EES contracts giving an indication of related experience.

Contract	Title or Description
DA36-039 SC-56761	Polarization Characteristics of Radar Targets
DA36-039 SC-64713	Polarization Characteristics of Radar Targets
DA36-039 SC-85363	Stability Studies of Quartz Crystals for Satellites
Nonr-991(10)	Microwave Techniques
NAS8-25192	Space Vehicle Electrical Power Systems
DAAG39-73-C-0116	Research and Development on Radar Antennas

3.0 EXPERIMENT FACTS

3.1 WHAT SPECIFIC SPACE PROPERTIES WILL IT MAKE USE OF?

Weightlessness, frictionless motion, lack of atmosphere.

3.2 WHAT IS THE PREFERRED LOCATION ON LDEF?

LEADING SIDE	______	SPACE END	______
TRAILING SIDE	X	INTERIOR	______
EARTH END	______		

3.3 WHAT ARE THE ENVIRONMENTAL CONSTRAINTS? (List extremes)

3.3.1 TEMPERATURE RANGE

-55 to +125°C

3.3.2 VIBRATION AND SHOCK (pre- and post-launch and orbit)

4 g

3.3.3 ATTITUDE CONTROL

0° rotation of LDEF

3.3.4 RADIATION (particles and electromagnetic)

3.3.5 VACUUM (space)

Hard vacuum

3.3.6 ATMOSPHERE (pre-, during, and post-launch and return)

No constraints

3.3.7 MAGNETIC FIELD Drone must be influenced by earth's magnetic field only. Modulators and transmitter are not affected by static or dynamic fields as they can be shielded.

3.4 WHAT SPECIAL PROTECTION MUST BE PROVIDED TO PROTECT THE EXPERIMENT FROM THE EARTH AND SPACE ENVIRONMENTS?

None

3.5 PHYSICAL DESCRIPTION

3.5.1 MASS

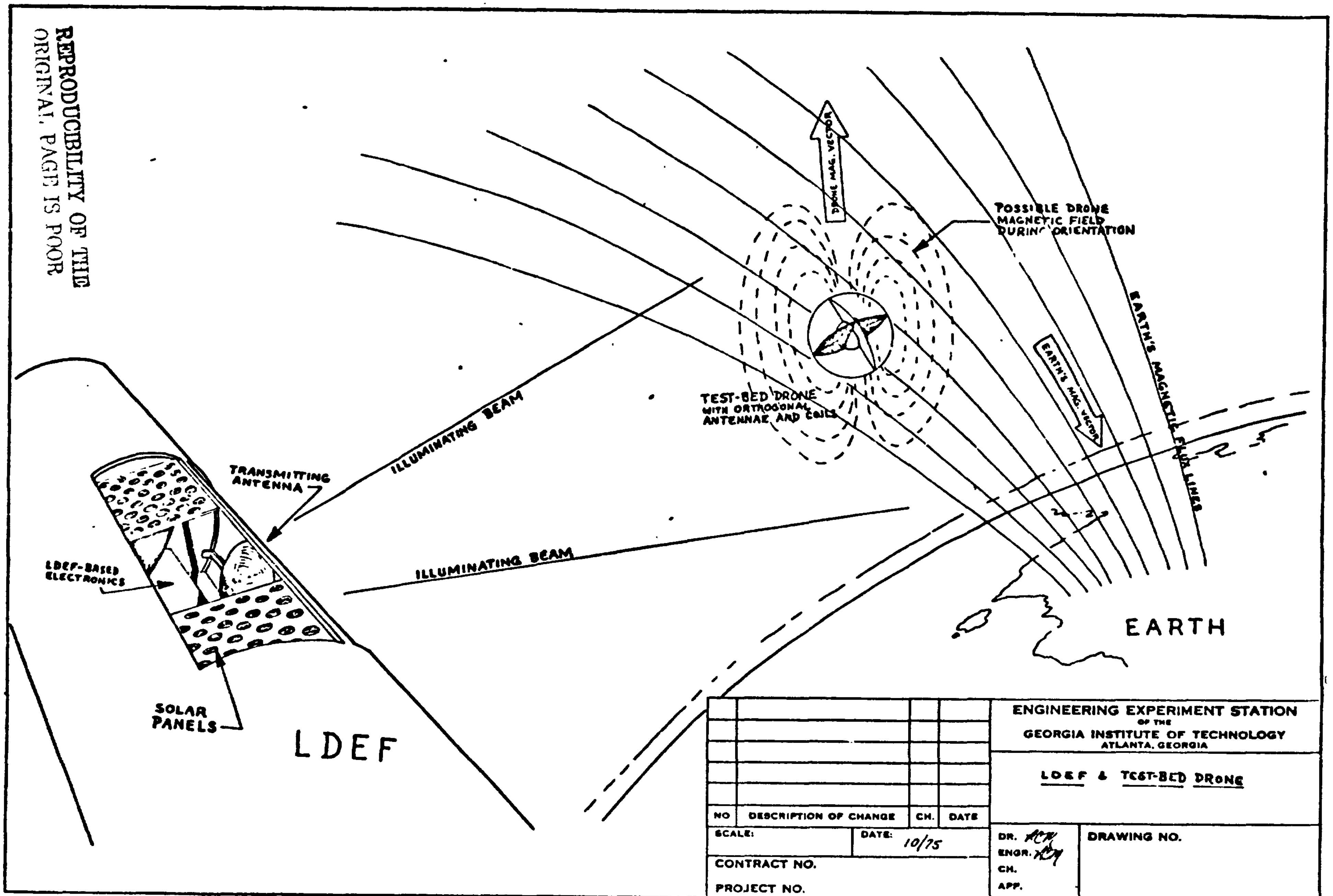
175 lbs.

3.5.2 VOLUME

27 cu ft

3.5.3 SURFACE AREA REQUIRED

10 sq ft


POSSIBLE DRONE MAGNETIC FIELD DURIN' ORIENTATION
DRONE MAG. VECTOR
EARTH'S MAG. VECTOR
EARTH'S MAGNETIC FLUX LINES
TEST-BED DRONE WITH ORTHOGONAL ANTENNAE AND COILS
ILLUMINATING BEAM
ILLUMINATING BEAM
TRANSMITTING ANTENNA
LDEF-BASED ELECTRONICS
SOLAR PANELS
LDEF
EARTH
NO
DESCRIPTION OF CHANGE
CH.
DATE
SCALE:
DATE: 10/75
CONTRACT NO.
PROJECT NO.
ENGINEERING EXPERIMENT STATION
OF THE
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA
LDEF & TEST-BED DRONE
DR.
ENGR.
CH.
APP.
DRAWING NO.

4.0 EXPERIMENT HARDWARE (With reference to the sketch in 3.6, briefly describe the hardware, indicating what is currently available and what must be developed.)

The figure on page 5 shows the LDEF containing the transmitting electronics and the synchronous drone test bed. All items listed below must be developed but are presently attainable within the limits of current technology.

LDEF:
- Digital controller
- Modulator
- Transmitter
- Drone position sensor
- Pencil beam transmitting antenna
- Battery pack w/solar recharge

Drone Test Bed:
- 3 orthogonal receiving antennas
- 3 orthogonal current loops
- Demodulator
- Digital processor
- Rectifier
- Storage cells (capacitive)
- Digitally controlled current sources

In addition an automatic releasing mechanism may be necessary for drone deployment.

5.0 DISCUSS RESEARCH REQUIRED TO DEVELOP EXPERIMENT

Research would pertain to the development of the subsystems listed in Section 4. In particular, the physical effects to be encountered by each of these subsystems would be subjects for research.

6.0 DISCUSS SPECIAL FACILITIES REQUIRED FOR DEVELOPMENT AND ANALYSIS

Vacuum chamber for preflight system integrity tests.

7.0 COST ESTIMATE (Manpower)

	mm	$
7.1 MANPOWER (Man-months and dollars)		
7.1.1 EXPERIMENT DESIGN	8	28,000
7.1.2 DEVELOPMENT OF IMPLEMENTATION PLAN	10	36,000
7.1.3 GROUND-BASED TESTING	2	7,000
7.1.4 PRE-LAUNCH (analysis)	1	3,500
7.1.5 DURING MISSION	2	7,000
7.1.6 POST-LAUNCH (analysis)	3	10,500
7.2 HARDWARE (Dollars)		
7.2.1 ENGINEERING PROTOTYPE		15,000
7.2.2 HARDWARE FABRICATION		35,000
7.2.3 PRE- AND POST-LAUNCH		
7.3 OTHER DIRECT COSTS (computer, travel, etc.)		3,000

$145K Total

8.0 SAFETY CONSIDERATIONS (Discuss potential hazards to ground and flight personnel, spacecraft, and other experiments.)

None anticipated

9.0 DISCUSS INTERACTIONS WITH SPACECRAFT AND OTHER EXPERIMENTS (e.g., thermal, radiation, mechanical).

Presence of drone test bed in vicinity of LDEF may affect experiments measuring magnetic fields. Blockage of any optical experiments aimed toward the drone might occur. Microwave transmissions from the LDEF portion of the experiment could affect nearby experiments.

PROPOSED EXPERIMENT FOR SPACE SHUTTLE

January 8, 1976

EXPERIMENT TITLE: Radio Astronomy of Molecular Oxygen from the Space Shuttle

EXPERIMENTER(S): Mr. J. J. Gallagher, Engineering Experiment Station, Georgia Tech

Dr. G. T. Wrixon, University of Cork, Cork, Ireland

Dr. L. Snyder, University of Virginia, Charlottesville, Va.

Dr. W. Welch, University of California, Berkeley, California

TECHNICAL ABSTRACT

Emission from molecular oxygen in interstellar space cannot be observed by radio astronomy techniques from ground-base telescopes, due to the large absorption of oxygen in the atmosphere. The techniques for satellite radiometric observations will be established for the 5 millimeter wavelength region. Calculations will be performed to determine the region in space for observations of molecular oxygen; the required radiometric sensitivity will be determined for the observations, and the antenna tracking scheme to observe the O_2 region from the space shuttle will be determined. Following the design and construction of the 5 millimeter radiometer, observations will be performed from the space shuttle. Data processing of the radiometric measurements will be made on the basis of the calculations performed during the initial stages of the investigation. Location of and concentration of molecular oxygen will be determined from the results of the measurements. This experiment will allow the first evaluation of radio astronomy observations from a space vehicle. The extension of these techniques to the shorter wavelengths of the submillimeter wavelength region will provide the mechanism for studying molecular species which have transitions in the submillimeter wavelength region, strongly shielded from earth observations by the absorption from oxygen and water vapor in the atmosphere.

BENEFITS/JUSTIFICATION FOR RESEARCH PROJECT

The strong absorption of millimeter radiation by atmospheric molecular oxygen and water vapor prevents the observation from earth of several molecular species which are predicted to exist in interstellar space; no other means exists for these observations except from a space vehicle such as the shuttle. The

experiments will permit not only the determination of oxygen in space, but will provide the basis for future observations at millimeter and submillimeter wavelengths.

1.0 TECHNICAL DISCUSSION OF EXPERIMENT APPROACH AND OBJECTIVES

It is proposed that an experiment be performed in the spectral region of 5 millimeters to observe the presence in interstellar space of molecular oxygen. Sensitive radiometers have been developed at this wavelength for observations of oxygen in the earth's atmosphere. The following steps constitute the approach to the problem:

1. Theoretical calculations will be performed to determine the requirements on the sensitivity of the radiometer and the location of the molecular oxygen in space.

2. On the basis of the determinations of 1., the antenna system, tracking techniques and radiometer will be designed. The exact frequencies, and number of oxygen transitions will have been determined for the observations and the radiometer will be designed to meet these parameters.

3. Following the experiment design, an engineering prototype will be assembled. Pre-flight testing will be followed by the assembling of the flight apparatus.

4. Schemes for tracking the O_2 region will be developed. Synthetic aperture techniques will be explored for this phase of the system.

5. Observations will be performed for a period up to 6-months in the Shuttle or for a period designated by NASA. The flight observations would be performed by J. J. Gallagher or a scientist chosen for the task.

6. Analysis of the data for concentrations, line shapes and regions of concentration of O_2 will be performed. These observations will be the first millimeter astronomy from a platform above the strongly absorbing atmosphere of earth, and will establish the techniques to be employed in future satellite astronomy at millimeter and submillimeter wavelengths.

The availability of an observer aboard the space vehicle provides great flexibility for tuning, calibration, repair and program changes in flight. In addition, the possibility of preliminary on-board data processing exists.

2.0 DISCUSS YOUR RELATED WORK AND EXPERIENCE

The experimenters have a broad background in related work. Dr. Welch and Dr. Snyder are radio astronomers with extensive experience in molecular phenomena in interstellar space. Dr. Welch's experience extends into the millimeter wavelength region, and his group at the University of California is currently assembling a radiometric system at 115 GHz. Dr. Wrixon is experienced in radio astronomy and atmospheric absorption, and has designed radiometers to wavelengths as short as 1.3 mm. His current experience in Schottky-barrier diode fabrication and design of 183 GHz radiometric components is related to the proposed task.

Mr. Gallagher has over 20 years experience in millimeter/submillimeter research including atmospheric spectroscopy and instrumentation. His current participation on NASA Grant No. NSG 5012 includes research on radiometers at 3 mm and 1.8 mm, atmospheric propagation studies and theoretical analysis of molecular interactions. The staff at Georgia Tech includes individuals experienced in millimeter wave instrumentation and applications. Members of the staff are experienced in design, construction and testing of satellite apparatus, and while employed at Martin Marietta were responsible for design and construction of the ATS-E millimeter wave equipment.

3.0 EXPERIMENT HARDWARE

The apparatus for this experiment is mainly within the current state-of-the-art of millimeter wave radiometry. Attention will have to be given to antenna development for tracking of the O_2 region, and development of calibration and flight operation procedures will have to be established.

4.0 DISCUSS RESEARCH REQUIRED TO DEVELOP EXPERIMENT

Antenna development will be necessary; all other developments will employ current state-of-the-art technology and will only require integration of the components testing under flight conditions and establishment of observational procedures.

5.0 DISCUSS SPECIAL FACILITIES REQUIRED FOR DEVELOPMENT AND ANALYSIS

Environmental flight testing facilities are needed.

6.0 COST ESTIMATE (Manpower)

		mm	$
6.1	MANPOWER (Man-months and dollars) Includes overhead	mm	$
6.1.1	EXPERIMENT DESIGN	24	88.5K
6.1.2	DEVELOPMENT OF IMPLEMENTATION PLAN	15	56K
6.1.3	GROUND-BASED TESTING	36	135K
6.1.4	PRE-LAUNCH (analysis)	24	88.5K
6.1.5	DURING MISSION	15	56K
6.1.6	POST-LAUNCH (analysis)	36	135K
6.2	HARDWARE (dollars)		
6.2.1	ENGINEERING PROTOTYPE		200K
6.2.2	HARDWARE FABRICATION		150K
6.2.3	PRE- AND POST-LAUNCH		100K
6.3	OTHER DIRECT COSTS (computer, travel, etc.)		60K
		TOTAL	1069K

EXPERIMENT TITLE Effect of Space Environment on The Mechanical and Electromagnetic Properties of Exposed Microstrip Antennas.

EXPERIMENTER(S) J. W. Cofer

POSITION Senior Research Engineer

ORGANIZATION Engineering Experiment Station

ADDRESS Georgia Insititute of Technology

Atlanta, Georgia 30332

TELEPHONE (404) 894-3591

TECHNICAL ABSTRUCT (50 words or less)

Thin conformal microstrip antenna elements and arrays are finding extensive use in space applications. The performance of such antennas is highly dependent on mechanical shape and dimensions and substrate parameters. The LDEF experiment offers an excellent opportunity to deploy and retrieve several typical elements and determine any degradation in electromagnetic performance due to exposure to the space environment.

BENEFITS/JUSTIFICATION FOR RESEARCH PROJECT

The beneficial output of such an undertaking would be valuable input to the design of such antennas for future spacecraft. Consequently, fewer communication and telemetry failures due to antenna damage would result.

1.0 TECHNICAL DISCUSSION OF EXPERIMENT APPROACH AND OBJECTIVES

A number of microstrip elements and arrays would be designed and fabricated at Georgia Tech or solicited from current vendors and tested in a laboratory environment. The antenna would be selected to cover a broad frequency range (most likely 400 MHz to 10 GHz) and several functions. The radiation parameters of the antennas selected will be carefully measured and documented. Specific parameters to be investigated include input impedance, resonance frequency, rf bandwidth, voltage-standing-wave ratio, and radiation pattern shape. The test antennas would then be mounted on a suitable structure which could be easily attached to and detached from the test vehicle. Upon recovery of the experiment package, each antenna would be subjected to the same previous series of tests. Of course, any physical damage due to thermal extremes, vacuum, vibration, shock, or particle bombardment would be noted. Such an experiment would provide design data in the areas of conductor and substrate thicknesses, physical shape, conductor coatings, and substrate material.

2.0 DISCUSS YOUR RELATED WORK AND EXPERIENCE

Several groups within Georgia Tech's Engineering Experiment Station are currently involved in the design and fabrication of microstrip and stripline components for the transmission and radiation of electromagnetic energy. The most recent effort is an internally sponsored program whose objective is the postulation and verification of new lightweight antenna schemes. Part of this program involves the design, development, and testing of stripline components and microstrip radiators.

On a previous project sponsored by the Applied Physics Laboratory, a thin patch radiator was developed which radiated at both 150 and 400 MHz. A number of broadband spiral antennas have been developed for missile seeker applications by photo-etching copper-clad printed circuit board.

In addition to these and other similar programs, the Engineering Experiment Station has a long history of successful activity in a wide range of technical disciplines with particular emphasis on the areas of communications, radar, and antennas.

3.0 EXPERIMENT FACTS

3.1 WHAT SPECIFIC SPACE PROPERTIES WILL IT MAKE USE OF?

Vacuum, temperature extremes, particle bombardment

3.2 WHAT IS THE PREFERRED LOCATION ON LDEF?

LEADING SIDE	______	SPACE END	Slight preference
TRAILING SIDE	______	INTERIOR	______
EARTH END	______		

3.3 WHAT ARE THE ENVIRONMENTAL CONSTRAINTS? (List extremes)

3.3.1 TEMPERATURE RANGE Normal temperatures experienced throughout test orbit.

3.3.2 VIBRATION AND SHOCK (pre- and post-launch and orbit)

It is anticipated that vibration and shock (short of vehicle deformation) will be of little consequence.

3.3.3 ATTITUDE CONTROL

No constraint.

3.3.4 RADIATION (particles and electromagnetic) This constraint is unknown and is one of the objectives of the experiment.

3.3.5 VACUUM (space)

Constraint unknown but probably of little significance.

3.3.6 ATMOSPHERE (pre-, during, and post-launch and return)

It is assumed that vehicle skin temperatures during launch and reentry will not reach the point of destroying antennas.

3.3.7 MAGNETIC FIELD

No constraint

3.4 WHAT SPECIAL PROTECTION MUST BE PROVIDED TO PROTECT THE EXPERIMENT FROM THE EARTH AND SPACE ENVIRONMENTS?

None except as noted in 3.3.6 above.

3.5 PHYSICAL DESCRIPTION

3.5.1 MASS 10-20 lbs.

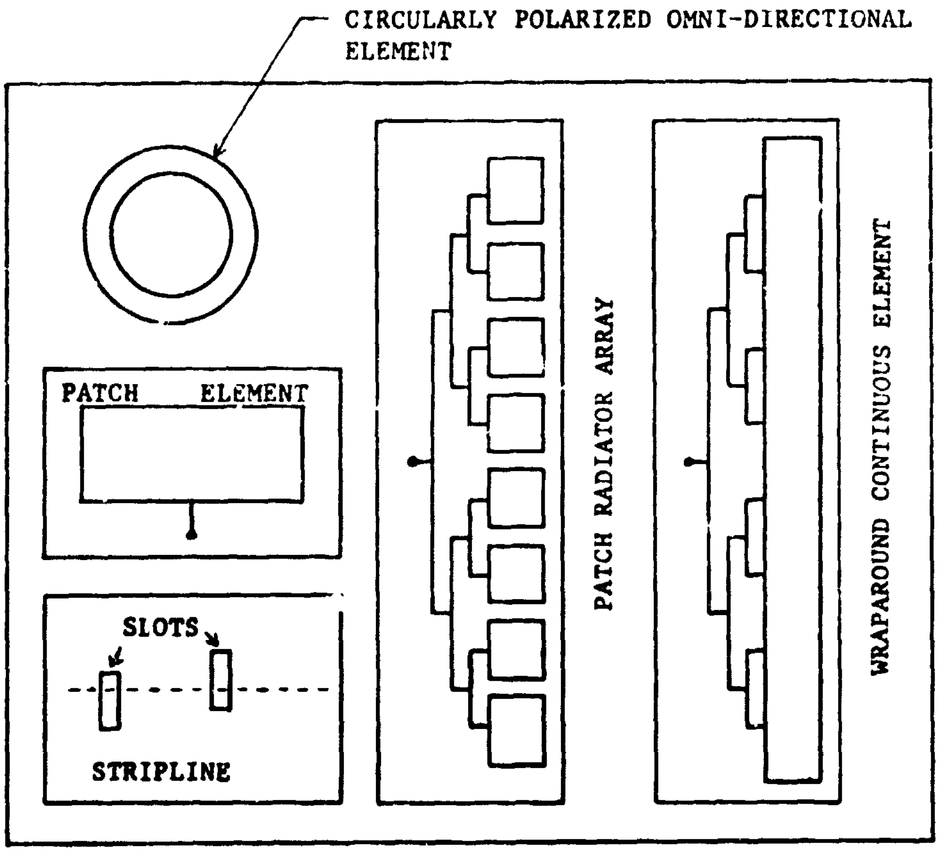
3.5.2 VOLUME 30 in. by 36 in. by 6 in. deep

3.5.3 SURFACE AREA REQUIRED

30 in. by 36 in.

3.6 SKETCH EXPERIMENT INCLUDING MAJOR COMPONENTS AND LAYOUT FOR EXPOSURE EXPERIMENTS.

The experiment hardware will be a number of typical elements arranged on a mounting frame as shown below. The frame shown is approximately 30 inches square and would require a depth of no more than six inches (two inches would be typical).



MOUNTING FRAME

4.0 EXPERIMENT HARDWARE (With reference to the sketch in 3.6, briefly describe the hardware, indicating what is currently available and what must be developed.)

The experiment hardware will consist totally of thin microstrip antennas and any associate electromagnetically transparent antenna covering. The elements included will be typical of those currently in use or those resulting from Georgia Tech's ongoing internal program. It is anticipated that the subject antennas will be fabricated by EES personnel although established commercial suppliers may be asked to furnish typical devices.

5.0 DISCUSS RESEARCH REQUIRED TO DEVELOP EXPERIMENT

A brief survey conducted among NASA engineers and satellite antenna vendors will yield the type of antennas most commonly used. Beyond this, the experiment will consist of state-of-the-art design, fabrication and testing activities; however, the test results upon vehicle return could show that more research is needed in this area to increase antenna life.

6.0 DISCUSS SPECIAL FACILITIES REQUIRED FOR DEVELOPMENT AND ANALYSIS

A number of special facilities and equipment will be required; however, all of these are presently available at Georgia Tech for use on programs such as that proposed. In particular, such items as photo-etching facilities, anechoic chambers, rf network analyzers, and radiation pattern recording ranges are some of the more important facilities which are available.

7.0 COST ESTIMATE (Manpower)

	mm	$ *
7.1 MANPOWER (Man-months and dollars)		
7.1.1 EXPERIMENT DESIGN	2	7,100
7.1.2 DEVELOPMENT OF IMPLEMENTATION PLAN	1	3,550
7.1.3 GROUND-BASED TESTING	2	7,100
7.1.4 PRE-LAUNCH (analysis)	0	0
7.1.5 DURING MISSION	0	0
7.1.6 POST-LAUNCH (analysis)	2	7,100
7.2 HARDWARE (Dollars)		
7.2.1 ENGINEERING PROTOTYPE		1,500
7.2.2 HARDWARE FABRICATION		3,000
7.2.3 PRE- AND POST-LAUNCH		0
7.3 OTHER DIRECT COSTS (computer, travel, etc.)		1,400

1.0 hour on Georgia Tech owned computer at $400/hr. = $400

5 man-trips to vendors facilities at $200/trip = $1000

*These wage rates correspond to the average rate of a Senior Research Scientist within the Systems and Techniques Laboratory of EES for the fiscal year 1976 and include overhead and employee benefit charges of 77%.

8.0 SAFETY CONSIDERATIONS (Discuss potential hazards to ground the flight personnel, spacecraft, and other experiments.)

This experiment is completely passive and contains no dangerous materials; consequently, it presents absolutely no threat to the safety of ground or flight personnel, the spacecraft, or other experiments.

9.0 DISCUSS INTERACTIONS WITH SPACECRAFT AND OTHER EXPERIMENTS (e.g., thermal, radiation, mechanical).

The experiment package will be thermally isolated from the spacecraft and will neither radiate nor consume energy; therefore no interaction is anticipated.

EXPERIMENT TITLE Photocatalytic syntheses on Siliceous Particles under Conditions of Weightlessness and Solar Ultraviolet Light.

	Principal Investigator	Associate Investigator
EXPERIMENTER(S)	Jerry S. Hubbard, Ph.D	Gerald E. Voecks, Ph.D.
POSITION	Assoc. Prof. of Biology	Senior Scientist
ORGANIZATION	Georgia Institute of Technology	Jet Propulsion Laboratory California Institute of Technology
ADDRESS	Atlanta, Georgia 30332	Pasadena, California 91103
TELEPHONE	404-894-3738	213-354-6645

TECHNICAL ABSTRACT (50 words or less)

Photocatalytic syntheses will be studied. Sealed quartz tubes containing siliceous particles and atmospheres of ^{14}CO or ^{14}CO and NH_3 will be exposed to solar radiation aboard the LDEF. Analysis of ^{14}C products will be made on returned samples. The findings will be used to assess the contributions of these processes in chemical evolution in planetary atmospheres and interstellar space.

BENEFITS/JUSTIFICATION FOR RESEARCH PROJECT

Our discoveries of photocatalytic syntheses of organic compounds on siliceous surfaces have raised new questions concerning the processes of chemical evolution in planetary atmospheres and in interstellar space. Using ultraviolet lamps simulating the solar spectrum we showed that the surface dependent syntheses are catalyzed at low light intensities at wavelengths longer than those absorbed by the gaseous reactants. Moreover, the surface has a protective function in preventing photodestruction of the products. The LDEF provides a unique opportunity to assess the importance of these reactions. Syntheses can be carried out under true solar radiation and weightlessness will permit maximum exposure of the particles to the light and will minimize the contributions of "wall effects".

1.0 TECHNICAL DISCUSSION OF EXPERIMENT APPROACH AND OBJECTIVES

The objectives are to investigate the influence of solar radiation and weightlessness on the photocatalytic syntheses on siliceous surfaces. Previous findings in the investigators' laboratories have indicated that these processes may have been of importance in chemical evolution on planetary surfaces, on particles in planetary atmospheres and on grain surfaces in interstellar clouds. Detailed discussions of these processes are given in the publications listed on page 3 of this proposal. Briefly, we have shown that simulated solar radiation catalyzes surface - dependent syntheses of simple organic compounds from CO and H_2O or CO and NH_3. The unique aspect of the reactions is that they are catalyzed by low intensity light sources at wavelengths longer than those absorbed by gaseous reactants. Of additional significance is the fact that the surface material serves to protect the products from photodestruction. The LDEF provides an unparalleled opportunity to assess the importance of these processes under realistic conditions. The solar spectrum cannot be duplicated in the laboratory. Also, the condition of weightlessness will permit maximum exposure of the particles to the light and will minimize the interaction of particles and atmosphere at the walls of the reaction tube.

The flight experiment will consist of a series of 16 sealed quartz tubes which are preloaded with specially prepared silica gel and an atmosphere of ^{14}CO or ^{14}CO and NH_3. Tubes will be mounted to a reflective plate and oriented so as to receive maximum levels of sunlight. Four sets of four tubes will comprise the package. One set will contain ^{14}CO and silica gel with a moderate level of hydration. The second set will be similar except that silica gel will be extremely dry. The third set will contain ^{14}CO and silica gel which has been pretreated with high levels of NH_3. The fourth set will differ in that the excess NH_3 will be pumped away. One tube from each set will be covered with an opaque material so as to serve as the unirradiated control.

The ground base controls will consist of two additional series of experiments. One series will be irradiated with a laboratory light source during the mission. The second series will be kept in the dark during the mission.

The analysis of the gas phase will be performed by separating the ^{14}C-components by gas chromatography, trapping the individual peaks and determining their radioactivity. ^{14}C-Organic products will be identified and quantitated by thin layer chromatographic and autoradiographic analyses of aqueous extracts of the surface material. The methods for the analyses have been published (page 3). Comparisons of the relative yields of the products from the LDEF tests and ground base controls will give a measure of effectiveness of solar radiation in catalyzing these processes.

2.0 DISCUSS YOUR RELATED WORK AND EXPERIENCE

J. S. Hubbard, Ph.D. (Microbiology)
1966-1973. Jet Propulsion Laboratory (Senior Scientist, Member of Technical Staff, Group Supervisor).
Co-developer of the Pyrolytic Release Experiment on the 1976 Viking Lander
Discovery of photocatalytic synthesis on simultated planetary surfaces.

1973-1974. Senior Biologist, California Institute of Technology.
Investigations related to instrument development and scientific strategies for the Viking mission.

1974-present. Associate Professor, Georgia Institute of Technology.
Principal Investigator NASA Grant NSG 7069 Photocatalytic Synthesis on Planetary Surfaces; Molecular Bases for the Adaptation of Halophilic Microorganisms.

Principal Investigator, NASA Contract NAS1-13422. Science Support Studies for the Pyrolytic Release Experiment, Viking Biology Instrument.

Viking Flight team member; Associate to Viking Biology Team; Member, Viking Surface Sampler Team.

Study Groups and Committees:

AIBS-NASA Study on the Future Use of the Lunar Receiving Laboratory, 1969-1970; National Research Council _ad hoc_ Committee on the Definition of Parameters for Planetary Quarantine Policy, Woods Hole, Mass., July, 1970; NASA study group on the design of a mission for a return Mars sample, 1972-1973 (NASA TM X-3184).

Publications related to proposal objectives:

Hubbard, J. S., J. P. Hardy and N. H. Horowitz. Photocatalytic production of organic compounds from CO and H_2O in a simulated martian atmosphere. Proc. Nat. Acad. Sci., USA, _68_: 574-578 (1971)

Hubbard, J. S., J. P. Hardy, G. E. Voecks and E. E. Golub. Photocatalytic synthesis of organic ompounds from CO and water: involvement of surfaces in the formation and stabilization of products. J. Molecular Evolution, _2_: 149-166 (1973).

Ferris, J. P., E. A. Williams, D. E. Nicodem, J. S. Hubbard and G. E. Voecks. Photolysis of CO-NH_3 mixtures and the Martian atmosphere. Nature _249_: 437-438 (1974).

Hubbard, J. S., G. E. Voecks, G. L. Hobby, J. P. Ferris, E. A. Williams and D. E. Nicodem. Ultraviolet-gas phase and -photocatalytic synthesis form CO and NH_3. J. Mol. Evol. _5_ 223-241 (1975)

G. E. Voecks, Ph.D. (Inorganic Chemistry).
1972-1974. NASA-NRC Resident Research Associate, Jet Propulsion Laboratory. Investigations on the mechanisms of Photocatalytic Syntheses (See above publications).
1974-present. Senior Scientist, Fuel Conversion Group, Jet Propulsion Laboratory.
Research on the catalytic combustion of fuels with emphasis on the particulate interactions with gaseous products.

3.0 EXPERIMENT FACTS

3.1 WHAT SPECIFIC SPACE PROPERTIES WILL IT MAKE USE OF?

weightlessness, solar radiation

3.2 WHAT IS THE PREFERRED LOCATION ON LDEF?

LEADING SIDE		SPACE END	Required
TRAILING SIDE		INTERIOR	
EARTH END			

3.3 WHAT ARE THE ENVIRONMENTAL CONSTRAINTS? (List extremes)

3.3.1 TEMPERATURE RANGE - **as low as permitted**

3.3.2 VIBRATION AND SHOCK (pre- and post-launch and orbit)
no constraints

3.3.3 ATTITUDE CONTROL
no constraints

3.3.4 RADIATION (particles and electromagnetic)
maximum exposure to sunlight

3.3.5 VACUUM (space) **no constraints**

3.3.6 ATMOSPHERE (pre-, during, and post-launch and return)
no constraints

3.3.7 MAGNETIC FIELD **no constraints**

3.4 WHAT SPECIAL PROTECTION MUST BE PROVIDED TO PROTECT THE EXPERIMENT FROM THE EARTH AND SPACE ENVIRONMENTS?
the experimental material is enclosed in sealed tubes - no constraints

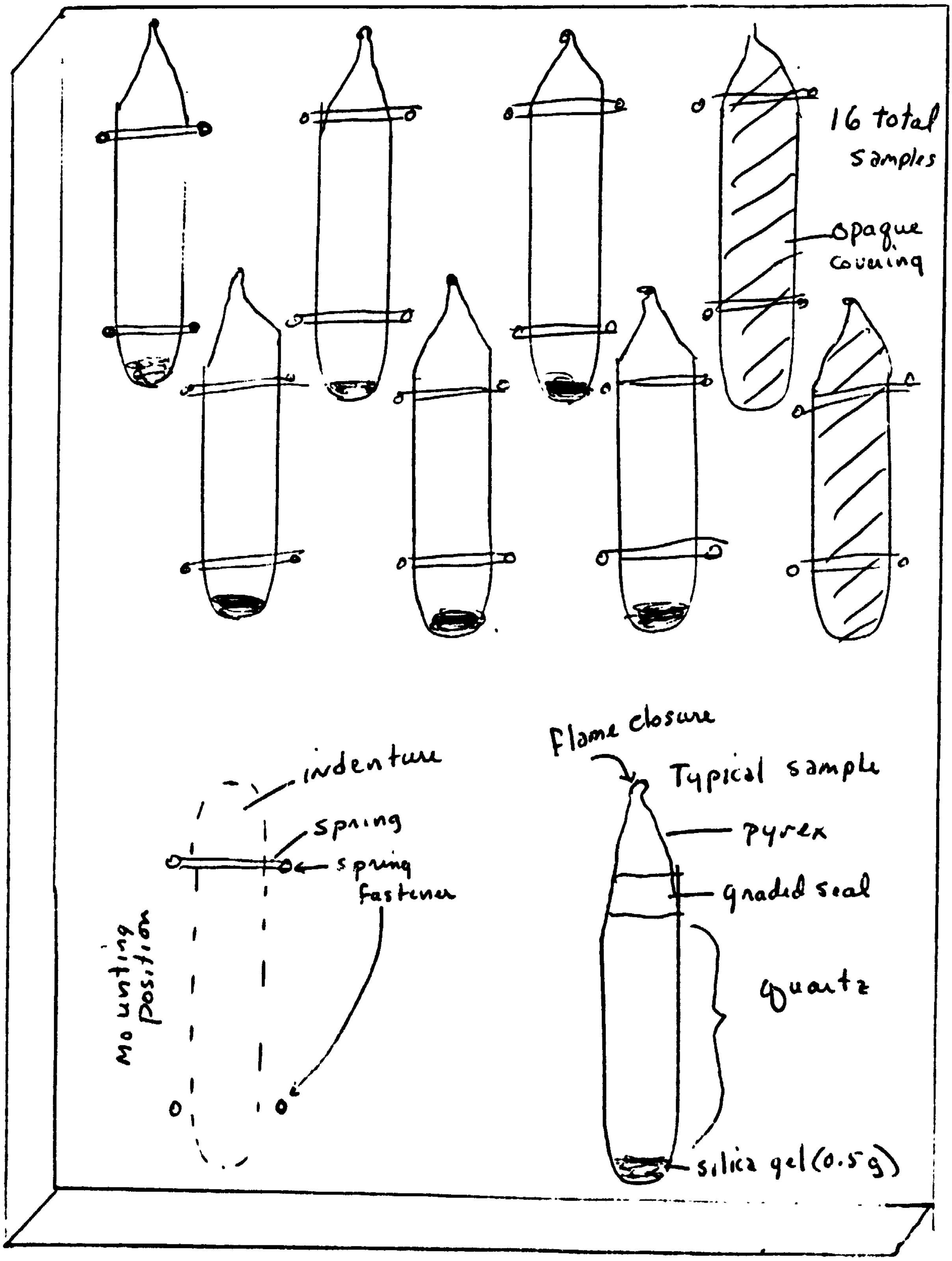
3.5 PHYSICAL DESCRIPTION

3.5.1 MASS **2 lbs including sample holder**

3.5.2 VOLUME **1 ft x 1 ft x 2 inches**

3.5.3 SURFACE AREA REQUIRED **1 ft^2**

3.6 SKETCH EXPERIMENT INCLUDING MAJOR COMPONENTS AND LAYOUT FOR EXPOSURE EXPERIMENTS. Approximately to scale



polished aluminum block

4.0 EXPERIMENT HARDWARE (With reference to the sketch in 3.6, briefly describe the hardware, indicating what is currently available and what must be developed.)

Required: fabrication of the aluminum block assembly, quartz-pyrex tubes and other apparatus for attachment to spacecraft

5.0 DISCUSS RESEARCH REQUIRED TO DEVELOP EXPERIMENT

The background research has been completed. Construction of a sample holder and loading of the sample tubes is required.

6.0 DISCUSS SPECIAL FACILITIES REQUIRED FOR DEVELOPMENT AND ANALYSIS

Adaptation of existing vacuum system in the principal investigators laboratory for preparation and analysis of samples.

7.0 COST ESTIMATE (Manpower)

	mm	$*
7.1 MANPOWER (Man-months and dollars)		
7.1.1 EXPERIMENT DESIGN	2	7.2K
7.1.2 DEVELOPMENT OF IMPLEMENTATION PLAN	0	0
7.1.3 GROUND-BASED TESTING	0.5	1.8K
7.1.4 PRE-LAUNCH (analysis)	0.5	1.8K
7.1.5 DURING MISSION	0	0
7.1.6 POST-LAUNCH (analysis)	2	7.2
7.2 HARDWARE (Dollars)		
7.2.1 ENGINEERING PROTOTYPE		0.5K
7.2.2 HARDWARE FABRICATION		3K
7.2.3 PRE- AND POST-LAUNCH		1K
7.3 OTHER DIRECT COSTS (computer, travel, etc.)		2.4K

*includes overhead and indirect costs

8.0 SAFETY CONSIDERATIONS (Discuss potential hazards to ground and flight personnel, spacecraft, and other experiments.)

The only potential concern is the ^{14}CO used in the sample tubes. Each tube will contain about 1 μCi of ^{14}C, a level which is well below safety hazard levels. The chemical quantity of CO is about 0.02 μmoles per tube, well below the chemical toxicity level.

9.0 DISCUSS INTERACTIONS WITH SPACECRAFT AND OTHER EXPERIMENTS (e.g., thermal, radiation, mechanical).

no obvious interactions

EXPERIMENT TITLE Experimental Space Craft Heat Engine

EXPERIMENTER(S) R. R. Sheppard

POSITION Assistant Research Engineer

ORGANIZATION Georgia Institute of Technology

ADDRESS 225 North Avenue

Atlanta, GA 30326

TELEPHONE 404-894-3576

TECHNICAL ABSTRACT (50 words or less)

It is proposed to fabricate and install an experimental heat engine to evaluate the feasibility of utilizing the extreme temperature differences aboard orbiting spacecraft to produce direct mechanical power.

BENEFITS/JUSTIFICATION FOR RESEARCH PROJECT

An increase in the mechanical power obtained from a given surface area over that produced by solar cells, can be obtained by employing a heat engine. Solar cells can be cooled to produce heat input to the heat engine system.

1.0 TECHNICAL DISCUSSION OF EXPERIMENT APPROACH AND OBJECTIVES

It is proposed to design and fabricate an experimental heat engine to evaluate the feasibility of utilizing the temperature extremes associated with the outer space environment to produce direct mechanical power. The power produced may be used to directly power experimental modules or to run electrical generators.

Solar cells operate more efficiently at low temperatures; however, temperature control of the cells is a problem. Solar cells may be used as a heat source for the engine. The engine working fluid would then take on the dual role of cooling the solar cells and providing input heat to the engine.

2.0 EXPERIMENT FACTS

2.1 WHAT SPECIFIC SPACE PROPERTIES WILL IT MAKE USE OF ?
Extreme thermal gradients

2.2 WHAT IS THE PREFERRED LOCATION OF LDEF?

LEADING SIDE ________ SPACE END XX

TRAILING SIDE ________ INTERIOR ________

EARTH END ________

2.3 WHAT ARE THE ENVIRONMENTAL CONSTRAINTS? (List extremes)

2.3.1 TEMPERATURE RANGE
-300 to 1200°F
2.3.2 VIBRATION AND SHOCK (pre- and post-launch and orbit)
Shock: 80 G, 0.5 μsec
acceleration { 30 g axial / ± 10 g lateral }
2.3.3 ATTITUDE CONTROL
None
2.3.4 RADIATION (particles and electromagnetic)
Not expected to affect operation of mechanism during 6 month duration of flight.
2.3.5 VACUUM (space)
None
2.3.6 ATMOSPHERE (pre-, during, and post-launch and return)
None
2.3.7 MAGNETIC FIELD
None

2.4 WHAT SPECIAL PROTECTION MUST BE PROVIDED TO PROTECT THE EXPERIMENT FROM THE EARTH AND SPACE ENVIRONMENTS?

The experiment will be designed such that protection measures are integral with the mechanism.

2.5 PHYSICAL DESCRIPTION

2.5.1 MASS
127 pounds
2.5.2 VOLUME
50 x 34 x 20 inches
2.5.3 SURFACE AREA REQUIRED
50 x 34 inches

3.0 EXPERIMENT HARDWARE

The hardware involved includes two heat exchangers, reheaters, a turbine, and a compressor. The thermal cycle invisioned for use is the standard gas Brayton cycle. The heat source exposed area is to be coated with a thermal control material with a solar absorbtivity, α_s, of 0.85 and an infrared emittance, ε, of 0.11. The sink surface area is to be coated with a material with $\alpha_s = 0.04$ and $\varepsilon = 0.85$. Engine output recording equipment will be used and the entire package designed as a self-contained unit.

4.0 DISCUSS RESEARCH REQUIRED TO DEVELOP EXPERIMENT

Heat engine theory and design is well documented and has been so for many years. Heat exchanger design is also well developed. The proposed heat engine requires the development of a system for the particular space environment and the problems associated with efficient heat exchange at the heat engine output, space environment interface.

5.0 DISCUSS SPECIAL FACILITIES REQUIRED FOR DEVELOPMENT AND ANALYSIS

Special facilities not presently available at Georgia Tech are not required.

6.0 ESTIMATED COST

6.1 Direct Salaries and Wages:		$58,429
Senior Research Engineers 3 man-mo. at avg. $2044/man-mo.	$6,132	
Research Scientists 6 man-mo. at avg. $1589/man-mo.	9,534	
Assistant Research Scientists 9 man-mo. at avg. $1239/man-mo.	11,151	
Machinists 16 man-mo. at avg. $973/man-mo.	15,568	
Technicians/Draftsmen 16 man-mo. at avg. $931/man-mo.	14,890	
Secretarial/Clerical/Photo Lab., Other, 3/4 man-mo. at avg. $673/man-mo.	504	
Graduate Research Assistants 1 man-mo. at avg. $650/man-mo.	650	
6.2 Overhead:		39,732
At a rate of 68% of direct salaries and wages.		
6.3 Retirement Benefits:		5,163
At 8.936% of applicable salaries and wages (excluding graduate and student assistants)		

6.4	Materials and Supplies:	$15,000
	Report reproduction and drafting supplies, mechanical equipment, raw materials, etc.	
6.5	Travel:	1,500
6.6	Final Report:	1,500
	Writing and printing of progress and final reports.	
6.7	Environmental Testing:	2,100
	Testing of design hardware.	
	TOTAL ESTIMATED COST	$123,424

7.0 SAFETY CONSIDERATIONS

The heat engine package should not affect in any manner ground and flight personnel, neighbor experimental trays or the space craft itself.

8.0 DISCUSS INTERACTIONS WITH SPACECRAFT AND OTHER EXPERIMENTS (e.g., thermal, radiation, mechanical).

The heat engine package will be self-contained. The package will interact only with the space environment through the exposed surface.

EXPERIMENT TITLE Space Testing of Holographic Data Storage Crystals

EXPERIMENTER(S) T. K. Gaylord and W. R. Callen

POSITION Assistant Professors

ORGANIZATION School of Electrical Engineering

ADDRESS Georgia Institute of Technology
Atlanta, Georgia 30332

TELEPHONE 404-894-2931; 404-894-2919

TECHNICAL ABSTRACT (50 words or less)

The eventual utilization of high capacity electro-optic memories in space applications has brought into focus the need to test the space-worthiness of such memory systems.

BENEFITS/JUSTIFICATION FOR RESEARCH PROJECT

A compact high bit capacity recorder (on the order of 10^{12} bits) and memory system does not exist at the present time. However, electro-optic holographic recording systems are being developed and appear to be extremely promising. The space testing of basic systems will help bring about the realization of these systems for both earth and space applications. Benefits will be accrued by all types of data base organizations (many government agencies and private industry).

1.0 TECHNICAL DISCUSSION OF EXPERIMENT APPROACH AND OBJECTIVES

To determine the fundamental space-worthiness and to identify possible unsuspected physical effects, it is proposed to carry five holographic data storage crystals on LDEF. This would be aimed at determining the effects of the combination of 1) temperature, 2) vacuum, and 3) acoustic and vibration levels.

Three of the lithium niobate crystals would contain recorded holograms and two would be unrecorded (control sample). Specifically the five crystals would be:

Crystal 1: heat treated (reduced at 200°C) for maximum writing sensitivity (maximum Fe^{+3}), blank;

Crystal 2: heat treated (oxidized at 200°C) for minimum writing sensitivity (maximum Fe^{+2}), blank;

Crystal 3: heat treated (reduced at 200°C) for maximum writing sensitivity (maximum Fe^{+3}), containing plane wave, digital data hologram;

Crystal 4: heat treated (oxidized at 200°C) for minimum writing sensitivity (maximum Fe^{+2}), containing plane wave, digital data hologram;

Crystal 5: heat treated (low temperature $\sim$ 100°C), "fixed" (ion drift process), containing plane wave, digital data hologram.

2.0 DISCUSS YOUR RELATED WORK AND EXPERIENCE

The experimenters have done extensive research in the area of holographic recording and optical memory systems. Publications in technical journals include:

1. T. K. Gaylord, T. A. Rabson, and F. K. Tittel, "Optically erasable and rewritable solid state holograms," Applied Physics Letters, vol. 20, no. 1, pp. 47-49, January 1, 1972.

2. T. K. Gaylord, "The high capacity storage problem: Is optical holography the answer?", Optical Spectra, vol. 6, no. 11, pp. 25-37, November 1972.

3. T. K. Gaylord, T. A. Rabson, F. K. Tittel, and C. R. Quick, "Self-enhancement of $LiNbO_3$ holograms," Journal of Applied Physics, vol. 44, no. 2, pp. 896-897, February 1973.

4. T. K. Gaylord, T. A. Rabson, F. K. Tittel, and C. R. Quick, "Pulsed writing of solid state holograms," Applied Optics, vol. 12, no. 2, pp. 414-415, February 1973.

5. T. K. Gaylord and F. K. Tittel, "Angular selectivity of lithium niobate volume holograms," Journal of Applied Physics, vol. 44, no. 9, pp. 4771-4773, September 1973.

6. P. Shah, T. A. Rabson, F. K. Tittel, and T. K. Gaylord, "Volume holographic recording and storage in Fe-doped $LiNbO_3$ using optical pulses," Applied Physics Letters, vol. 24, no. 3, pp. 130-131, February 1, 1974.

7. R. Magnusson and T. K. Gaylord, "Laser scattering induced holograms in lithium niobate," Applied Optics, vol. 13, no. 7, pp. 1545-1548, July 1974.

8. T. K. Gaylord, "Optical memories," Optical Spectra, vol. 8, no. 6, pp. 29-34, June 1974 and Optical Spectra, vol. 8, no. 9, pg. 11, September 1974.

9. S. F. Su and T. K. Gaylord, "Calculation of arbitrary-order diffraction efficiencies of thick gratings with arbitrary grating shape," Journal of the Optical Society of America, vol. 65, no. 1, pp. 59-64, January 1975.

10. T. K. Gaylord, "Optical memory systems," Optical Industry and Systems Directory Encyclopedia. Pittsfield, Mass., Optical Publishing Co., pp. 132-136, 1975.

11. C. O. Alford and T. K. Gaylord, "The potential of multi-port optical memories in digital computing," Digest of 1975 International Optical Computing Conference, pp. 121-123, Washington, D.C., April 1975.

12. S. F. Su and T. K. Gaylord, "Refractive index profiles and arbitrary-order diffraction efficiencies of lithium niobate holograms," Journal of the Optical Society of America, vol. 65, no. 10, pg. 1220, October 1975.

13. R. Magnusson and T. K. Gaylord, "Application of dynamic theory to the description of experimental volume holography," Journal of the Optical Society of America, vol. 65, no. 10, pg. 1219, October 1975.

14. S. F. Su and T. K. Gaylord, "Unified approach to the formation of phase holograms in lithium niobate," Journal of Applied Physics, vol. 46, pp. 5208-5213, December 1975.

15. T. K. Gaylord, J. E. Weaver, and W. R. Callen, "A mobile, rigid, vibration-isolated optics demonstration platform," American Journal of Physics, vol. 44, 1976.

16. R. Magnusson and T. K. Gaylord, "Use of dynamic theory to describe experimental results from volume holography," Journal of Applied Physics, vol. 47, pp. 190-199, 1976.

17. S. F. Su and T. K. Gaylord, "Determination of optically-induced refractive index grating profiles in ferroelectric crystals," Journal of the Optical Society of America, vol. 66, 1976 (in preparation).

3.0 EXPERIMENT FACTS

3.1 WHAT SPECIFIC SPACE PROPERTIES WILL IT MAKE USE OF?

combination of vibration, temperature, and vacuum

3.2 WHAT IS THE PREFERRED LOCATION ON LDEF?

LEADING SIDE	X	SPACE END	X
TRAILING SIDE	X	INTERIOR	
EARTH END			

3.3 WHAT ARE THE ENVIRONMENTAL CONSTRAINTS? (List extremes)

3.3.1 TEMPERATURE RANGE

large variation is desirable

3.3.2 VIBRATION AND SHOCK (pre- and post-launch and orbit)

large variation is desirable

3.3.3 ATTITUDE CONTROL

not critical

3.3.4 RADIATION (particles and electromagnetic)

not critical

3.3.5 VACUUM (space)

large variation is desirable

3.3.6 ATMOSPHERE (pre-, during, and post-launch and return)

not critical

3.3.7 MAGNETIC FIELD

not critical

3.4 WHAT SPECIAL PROTECTION MUST BE PROVIDED TO PROTECT THE EXPERIMENT FROM THE EARTH AND SPACE ENVIRONMENTS?

3.5 PHYSICAL DESCRIPTION

3.5.1 MASS

100 grams

3.5.2 VOLUME

100mm × 100mm × 20mm

3.5.3 SURFACE AREA REQUIRED

100mm × 100mm

3.6 SKETCH EXPERIMENT INCLUDING MAJOR COMPONENTS AND LAYOUT FOR EXPOSURE EXPERIMENTS.

Each of the five crystals will be 10mm $\times$ 10mm $\times$ 2mm in size. This will place large area sides parallel to surface of space craft and arranged side-by-side.

4.0 EXPERIMENT HARDWARE (With reference to the sketch in 3.6, briefly describe the hardware, indicating what is currently available and what must be developed.)

A crystal holding tray will be developed by Georgia Tech.

5.0 DISCUSS RESEARCH REQUIRED TO DEVELOP EXPERIMENT

Selection of materials, mechanical, and optical design of tray will be critical.

6.0 DISCUSS SPECIAL FACILITIES REQUIRED FOR DEVELOPMENT AND ANALYSIS

Detailed quantification of recorded holograms will be necessary on earth before and after launch. This will require special optics and optical power measuring equipment.

7.0 COST ESTIMATE (Manpower)

	mm	$
7.1 MANPOWER (Man-months and dollars)		
7.1.1 EXPERIMENT DESIGN	1	$ 2,500
7.1.2 DEVELOPMENT OF IMPLEMENTATION PLAN	1	2,500
7.1.3 GROUND-BASED TESTING	1	2,500
7.1.4 PRE-LAUNCH (analysis)	---	---
7.1.5 DURING MISSION	---	---
7.1.6 POST-LAUNCH (analysis)	2	5,000
7.2 HARDWARE (Dollars)		
7.2.1 ENGINEERING PROTOTYPE		5,000
7.2.2 HARDWARE FABRICATION		7,500
7.2.3 PRE- AND POST-LAUNCH		
7.3 OTHER DIRECT COSTS (~~computer~~, travel, etc.)		300
		$25,300

8.0 SAFETY CONSIDERATIONS (Discuss potential hazards to ground and flight personnel, spacecraft, and other experiments.)

none

9.0 DISCUSS INTERACTIONS WITH SPACECRAFT AND OTHER EXPERIMENTS (e.g., thermal, radiation, mechanical).

none

EXPERIMENT TITLE Creep-Rupture Characteristics of Refractory Metals

EXPERIMENTER(S) Dr. J. Richard Williams

POSITION Associate Dean and Associate Professor

ORGANIZATION Georgia Insitute of Technology

ADDRESS Atlanta, GA 30332

TELEPHONE (404) 894-3351

TECHNICAL ABSTRACT (50 words or less)

NASA currently has a strong and developing program aimed at examining various options for the generation of power in synchronous orbit and transmission to earth. The evaluation of some of these options, utilizing both nuclear and solar power, has been hampered by lack of data on creep-rupture characteristics of refractory materials. Tubes of tungsten alloys and other appropriate metals will be pressurized and maintained at a high temperature for the duration of the IDEF flight. The hard vacuum and zero g environment surrounding the tubes will simulate the conditions expected in synchronous orbit. The creep-rupture characteristics of interest will be determined from examination after the tubes are returned to earth.

BENEFITS/JUSTIFICATION FOR RESEARCH PROJECT

The data obtained from this research will enable a more accurate assessment of solar-thermal and nuclear power plant options which are under consideration by NASA contractors.

TECHNICAL DISCUSSION OF EXPERIMENT APPROACH AND OBJECTIVES

Small tubes of approximately one quarter inch diameter composed of tungsten and molybdenum alloys and other refractory metals of interest will be placed in an insulated electrically heated container which is vented to space. While in orbit the tubes' internal pressure will be maintained at an appropriate level so that over the period of the test some of the tubes will undergo deformation while others will burst. By monitoring the temperature, which will be held constant, and pressure over the duration of the tests and examining the tubes after they have been returned to earth, the appropriate creep-rupture characteristics can be determined. These data will be especially useful for power satellite evaluation.

2.0 DISCUSS YOUR RELATED WORK AND EXPERIENCE

Dr. Williams has over 10 years'experience performing research for NASA on large space power supplies. From 1967-72 he was responsible for research on the heat transfer characteristics of materials to be used in large space reactors. He also carried out an analytical program for the NASA Lewis Research Center on large nuclear MHD power supplied for space. When the nuclear space power and propulstion program was terminated in 1972, he became active in the field of solar energy, subsequently carrying out four research contracts in the solar area, including a study for NASA on an assessment of nuclear and solar power plant options for geosynchronous power generation. Dr. Williams is currently responsible for a $280,000 ERDA-sponsored project on the development of focusing collectors for power generation, and a separate ERDA-sponsored research project which involves the construction of a 54,000 ft^2 solar heated and air-conditioned building. He also is co-principal investigator of a solar agricultural drying project.

3.0 EXPERIMENT FACTS

3.1 WHAT SPECIFIC SPACE PROPERTIES WILL IT MAKE USE OF?
zero gravity and vacuum

3.2 WHAT IS THE PREFERRED LOCATION ON LDEF?

LEADING SIDE ____________ SPACE END ____________

TRAILING SIDE ____________ INTERIOR ____________

EARTH END ____________

3.3 WHAT ARE THE ENVIRONMENTAL CONSTRAINTS? (List extremes) none

3.3.1 TEMPERATURE RANGE

3.3.2 VIBRATION AND SHOCK (pre- and post-launch and orbit)

3.3.3 ATTITUDE CONTROL

3.3.4 RADIATION (particles and electromagnetic)

3.3.5 VACUUM (space)

3.3.6 ATMOSPHERE (pre-, during, and post-launch and return)

3.3.7 MAGNETIC FIELD

3.4 WHAT SPECIAL PROTECTION MUST BE PROVIDED TO PROTECT THE EXPERIMENT FROM THE EARTH AND SPACE ENVIRONMENTS?

none

3.5 PHYSICAL DESCRIPTION

3.5.1 MASS
200 kilograms

3.5.2 VOLUME
approximately 4' x 6' x 2'

3.5.3 SURFACE AREA REQUIRED
approximately 4' x 6'

4.0 EXPERIMENT HARDWARE (With reference to the sketch in 3.6, briefly describe the hardware, indicating what is currently available and what must be developed.)

refractory metal tubing
pressure manifolds
pressure transducers
thermocouples
temperature recording instruments
small helium tank with pressure regulator

The high temperature chamber must be extremely well insulated so that a solar cell array on the outside of the tray can provide adequate electric power to maintain the temperature and record the data.

5.0 DISCUSS RESEARCH REQUIRED TO DEVELOP EXPERIMENT

No special techniques require development.

6.0 DISCUSS SPECIAL FACILITIES REQUIRED FOR DEVELOPMENT AND ANALYSIS

none

7.0 COST ESTIMATE (Manpower)

		mm	$
7.1	MANPOWER (Man-months and dollars) 3 year program		
7.1.1	EXPERIMENT DESIGN	3 man months	7500
7.1.2	DEVELOPMENT OF IMPLEMENTATION PLAN	1 man month	2500
7.1.3	GROUND-BASED TESTING AND ASSEMBLY	6 man months	15,000
7.1.4	PRE-LAUNCH (analysis)	3 man months	7500
7.1.5	DURING MISSION	3 man months	1500
7.1.6	POST-LAUNCH (analysis)	4 man months	10,000
7.2	HARDWARE (Dollars)		
7.2.1	ENGINEERING PROTOTYPE		20,000
7.2.2	HARDWARE FABRICATION		15,000
7.2.3	PRE- AND POST-LAUNCH		8,000
7.3	OTHER DIRECT COSTS (computer, travel, etc.)		6,000

8.0 SAFETY CONSIDERATIONS (Discuss potential hazards to ground and flight personnel, spacecraft, and other experiments.)

Pressurized gases involved but at moderate pressures only. Experiments should impose no significant hazards.

9.0 DISCUSS INTERACTIONS WITH SPACECRAFT AND OTHER EXPERIMENTS (e.g., thermal, radiation, mechanical).

Possible off-gassing of tubing and insulating materials. This can be minimized as much as is required for the experiment.